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David K. Ferry, Regents' Professor

July 1, 1993

Quarterly Progress Report 93-1

Contract No.: N00014-93-1-0705 (ARPA work order A305)

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Co-Investigators: Dr. Michael N. Kozicki, Dr. David R. Allee

Progress:

Silicon-Dioxide as a Resist

We have rebuilt the carbon-enhanced vapor etching facility to provide better control over etch rates and uniformity. This has substantially improved the system. We have exposed SiO_2 in the electron-beam lithography facility in a process that provides carbon contamination of the sample. It is found that an exposure dose of 100 $\mu C/cm^2$ (roughly one-half that needed for PMMA) provides sufficient carbon to provide a 23:1 differential in the etch rate of the SiO_2. We are proceeding now to ascertain the resolution limits that can be obtained (previous work by one of the investigators, D. Allee, showed that direct e-beam damage of SiO_2 could achieve 8 nm resolution).

Arsenic-Sulfide as a Resist

We have developed improved techniques of deposition of As-S thin films, which provide for improved uniformity. In this case, the resist is activated by Ag to provide differential etch rates in a CF_4 plasma. A thin film of Ag is deposited on the As-S resist and then driven into the resist by an electron beam or by optical exposure. During the coming year, we will investigate this resist material.

STM/SFM Lithography

Three new types of scanning tunneling and force lithography have been developed. Nanometer scale patterns have been fabricated on a Langmuir-Blodgett deposited monolayer film of stearic acid using a scanning tunneling microscope in air. Carbon deposits build up underneath the tip for tip voltages with absolute value greater than 4 V. Using an atomic force microscope to image, lines 25 nm wide on a 60 nm period have been written. As confirmed with Auger electron spectroscopy, the unexposed film can be removed with a chloroform soak without affecting the existing carbon patterns, and no additional patterns could then be written because of the removal of the monolayer film.

The use of a scanning force microscope with a metallized tip to do selective area oxidation of silicon was demonstrated. Sub-100 nm lines have been achieved. The resolution may be improved even further by using a sharper SFM tip. Removal of the oxide lines with buffered hydrofluoric acid reveals trenches in the silicon consistent with silicon consumption in SiO_2 formation. The process is thought to be similar to plasma anodization.

A scanning tunneling microscope tip and a metallized scanning force tip have been used to selectively write oxidation patterns on a thin Si_3N_4 film on p^+-silicon. After etching the patterns in hydrofluoric acid, trenches are observed consistent with silicon consumption in the oxidation process. The patterns in the nitride film could be transferred to the underlying silicon with an ammonium fluoride etch. 250 nm resolution has been achieved.

In addition to various infrastructure projects and collaborations, our efforts are focused on using the first of these techniques to fabricate a gate electrode in a working field effect transistor. To our knowledge, this would be the first transistor partially patterned with scanning tunneling lithography.

Electron-Beam Lithography and Pattern Transfer

We have been preparing substrates, in which thin films of Si_3N_4 will be used to support PMMA for studies of ultimate resolution. The scanning Auger microprobe has been installed and characterized. We have been studying its use for identifying fragments of long-chain PMMA that are produced by the electron-beam. We have also rebuilt a special RIE system to provide slow etching of thin layers. Etch rates of 5 nm/minute have been achieved at low power in a CF_4 plasma.

Publications During the Period:

1. H.C. Day, D.R. Allee, R. George and V.A. Burrows, "Nanometer scale patterning of a monolayer Langmuir-Blodgett film with a scanning tunneling microscope in air," *Appl. Phys. Lett.*, , 62 (14), pp. 1629-1631, 5 April 1993.
2. H.C. Day, D.R. Allee, "Selective area oxidation of silicon with a scanning force microscope," *Appl. Phys. Lett.*, 62 (21), pp. 2691-2693, 24 May 1993.
3. H.C. Day, D.R. Allee, "Selective area oxidation of Si_3N_4 and Si with scanning tunneling and force microscopes," presented at the 37th International Symposium on Electron, Ion and Photon Beams, San Diego, California, June 1-4, 1993, to be published in JVST B.
4. M. N. Kozicki, S. Balster, A. Jenkins, M. Polacca, and V. Burrows, "Carbon and Sulfur Enhanced Vapor Etching of SiO_2 Films," Abstracts of the 183rd Meeting of the Electrochemical Society.
5. J. Allgaier, M. N. Kozicki, J. M. Ryan, D. K. Ferry, H. C. Day, and D. R. Allee, "Vapor Etching of Electron-Beam Exposed Silicon Dioxide Films," to be submitted to Applied Physics Letters.

Personnel:

Co-Investigators:

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Dr. David R. Allee, Assistant Professor of Electrical Engineering

Graduate Students Supported by ARPA:

H. C. Day, doctoral student
J. Allgaier, masters student
M. Khoury, masters student

Other Students Associated with the Program:

Mary Jo Rack, NSF MEADE* Fellow, doctoral student
H. Upadhyay, masters student
Susan Kersey, NSF MEADE* Fellow, masters student

*Graduate Engineering Education Program for Women, Minorities, and/or Disabled Persons; Dr. D. K. Ferry, Co-Principal Investigator.